Assessment of Ramp-Capability and Reserve Margin Requirement for the State of Tamil Nadu with High RE-Penetration for Year 2022

September 5th, 2019

Pritam Sunil    Dr. Ankita Samui    Suramya Dwivedi    Arun Unni    Dr. Ravi Segal

GE Energy Consulting,
Bangalore, India
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• Operating earnings and EPS, which is earnings from continuing operations excluding non-service-related pension costs of our principal pension plans.
• GE Industrial operating & Verticals earnings and EPS, which is operating earnings of our industrial businesses and the GE Capital businesses that we expect to retain.
• Industrial segment organic revenue, which is the sum of revenue from all of our industrial segments less the effects of acquisitions/dispositions and currency exchange.
• Industrial segment organic operating profit, which is the sum of segment profit from all of our industrial segments less the effects of acquisitions/dispositions and currency exchange.
• Industrial cash flows from operating activities (Industrial CFOA), which is GE’s cash flow from operating activities excluding dividends received from GE Capital.
• Capital ending net investment (ENI), excluding liquidity, which is a measure we use to measure the size of our Capital segment.
• GE Capital Tier 1 Common ratio estimate is a ratio of equity.
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➢ Statistical Analysis of Wind and Solar Generation Profiles for the year 2022
➢ Reserve requirement assessment based on vRE generation for the year 2022
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Introduction – Tamil Nadu (TN)

• One of the largest consumers of electricity (~9% of total energy consumption in FY 2016)
• High rate of electrification, highly urbanized population
• Domestic and industrial sectors are major drivers for electric demand
• Thermal power plants form the largest share of the generation mix (16,339 MW as of June 2019), includes allocation from Central Generating Stations
• Renewable capacity is the second largest installed capacity in the state with 13,117 MW as of June 2019.
• The Ministry of New and Renewable Energy (MNRE) has targeted a total capacity of renewable capacity in Tamil Nadu by 2022 of 20,784 MW (8,884 MW solar and 11,900 MW of wind)
Assumptions

- Day Ahead Sub-Hourly Wind and Solar profiles obtained from an external service provider for the year 2022.
- Sub-hourly load profile of TN was calculated from the load data available in Southern Regional Load Dispatch Centre (SRLDC) website for 2015 and extrapolated based on the peak demand of TN for the year 2022 (19th EPS).
- Sub-hourly data captures variation of vRE* in greater resolution than hourly values.
- Accuracy of statistical analysis performed with such data is higher.

Key results of analysis:

- Ramp rate requirement for the state.
- Identification of ramping events in an year.
- Reserve requirement on account of vRE*.

* vRE: variable Renewable Energy (wind and solar generation)
Description of Key terms

Statistical Analysis with wind and solar generation profiles

• **RE, Load and Net-Load Profile**
  - **RE Profile**: Sub-hourly (15 mins) wind and solar RE-profile (total 35040 samples)
  - **Load Profile**: Sub-hourly load profile of TN, was taken from SRLDC for 2015 and extrapolated based on the peak demand of TN for the year 2022 (total 35040 samples)
  - **Net-Load Profile**: Calculated by subtracting Sub-hourly RE profile from Sub-hourly Load (total 35040 samples)
  - **vRE variation**: Differential between the consecutive samples of combined wind and solar generation

• **Surface Plot**:
  - Surface plots are diagrams of three-dimensional data that is useful for investigating the desirable response values and operating conditions
  - RE, Load and Net-Load data points are plotted in Z axis as height in X-Y plane (Month in X-axis and Hours in Y-axis)

• **Net-Load Variation or Delta**:
  - Net-Load Variation is calculated by subtracting the consecutive sample of Net-Load to evaluate the Ramp-Up and Ramp-Down requirements on sub-hourly basis

• **Net-Load Range**:
  - Net-load capacity (Load-RE) is divided into buckets of equal size in the range from 0 MW to maximum Net-Load output
  - In each range the % instances /year has been counted to assess the statistical characteristics of different range of Net-Load variation
  - Net-Load ranges are categorized as low range, high range and highest range to access the operational characteristics of Net-Load Variation

• **Sigma Delta**:
  - Standard deviation of the variation in vRE generation
Statistical analysis with Load data, Wind and Solar profiles for year 2022

‘Tamil Nadu’
Month-wise maximum hourly generation for wind, solar and combined wind and solar profile are depicted.

Wind power generation peaks at ~10,763 MW during June-August, while the minimum is ~800 MW for a given time block around mid-day in January-May.

Solar power generation peaks at ~8,000 MW around mid-day during the period from Jan-May and Oct-Dec. Reduced peak is visible in June-Sept for wet-season.

Combined wind and solar peak at 17,877 MW around the mid day of June-Aug when both wind and solar are available.
Thermal units need to be Ramp-Up or Ramp-Down to compensate the variability of Net-Load.

Gas based plants such as the combined cycle units are important during the initial period of ramp up requirement in view of the longer start up time for the coal plants.
Net-Load Range for Tamil Nadu (TN)

<table>
<thead>
<tr>
<th>Net-Load Range (MW)</th>
<th>% Instances/Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-2110</td>
<td>8%</td>
</tr>
<tr>
<td>2111-4220</td>
<td>13%</td>
</tr>
<tr>
<td>4221-6330</td>
<td>23%</td>
</tr>
<tr>
<td>6331-8440</td>
<td>18%</td>
</tr>
<tr>
<td>8441-10550</td>
<td>15%</td>
</tr>
<tr>
<td>10551-12660</td>
<td>12%</td>
</tr>
<tr>
<td>12661-14770</td>
<td>6%</td>
</tr>
<tr>
<td>14771-16880</td>
<td>12%</td>
</tr>
<tr>
<td>16881-18990</td>
<td>15%</td>
</tr>
<tr>
<td>18991-21100</td>
<td>18%</td>
</tr>
</tbody>
</table>

- Sub-hourly (15 minutes) Net-Load Ranges (Divided into buckets of equal size), Net-Load Variation (Subtraction of the consecutive samples of Net-Load) was evaluated to calculate the % instances/year and % instances/month.

- Net-Load ranges are categorized as:
  - ✓ Low Net-Load Range: 0-7 GW → Blue
  - ✓ High Net-Load Range: 7-14 GW → Green
  - ✓ Highest Net-Load Range: 14-21.1 GW → Yellow

- Net-Load is in the range of 8.4-10.5 GW for 23% time in a year and the maximum instances occur during the high RE period (May to Sept).

- Indicator to evaluate the yearly and monthly distribution of Net-Load variation or ramping requirement.
Ramping Requirement with Low Net-Load Range (0-7 GW)

- Average hourly Net-Load variation for each month with low range of Net-Load variation are as depicted

- In this case the average Ramp-Up and Ramp-Down is concentrated mainly during the months June-Aug when High RE-Penetration and Low Load condition leads to low net loads. % instances in this case is low as compared to high Net-Load range.
Ramping Requirement with High Net-Load Range (7-14 GW)

- Average hourly Net-Load variation (Ramp-Up and Ramp-Down) for each month with high range of Net-Load variation are depicted. Average hourly Net-Load variation (ramping requirement) is uniformly distributed throughout the year.
Ramping Requirement with Highest Net-Load Range (14-21 GW)

- Average hourly Net-Load variation (The Ramp-Up and Ramp-Down) for each month with highest range of Net-Load variation is visualized in the figures. % instances are found to be very low and largely to cater the load demand during low RE periods.
The net load variation range (max and min) (ramping capability) is: +2,588 MW (10,551-12,660 MW range) to -2,490 MW (12,661-14,720 MW range)

The maximum Ramp Up or maximum Net-Load variation per hour is ~ 2.6 GW

The maximum Ramp Down or minimum Net-Load variation per hour is ~ 2.5 GW

Maximum Ramp-Up and Ramp-Down is occurring with High Net-Load range.

Capability to meet this variability is dependent on the extent of flexible generation available and the support from neighboring states.
Reserve requirement assessment based on vRE generation for year 2022

‘Tamil Nadu’
Reserve Requirement on account of vRE

- Trendline curve function, to determine the equation which can be used to calculate the reserve requirements from the data set is \(3 \times 10^{-3} - 100x^2 + 0.1257x - 32.589\)
- Based on the data set utilized for this analysis a 2.5σ covers more than 98% of the vRE variations.
- At 1σ the maximum reserve requirement for the projected vRE generation is ~720 MW.
- At 2.5σ the maximum reserve requirement for the projected vRE generation is ~1800 MW.
Reserve Requirement on account of vRE

- The carpet plot depicting the reserve requirement for the state of Tamil Nadu in 2022 based on combined vRE (Wind + Solar).

- Carpet plot is obtained by taking the average value of the reserve requirement (based on the combined wind and solar generation) of each hour of the day for each month.

- Wind and solar generation mostly complement each other, i.e. wind would be available during the night when solar is not present and solar is at its peak during the day when wind generation is low.

- The reserve requirements are highest during peak hours in June-August period which coincides with high variations in vRE generation.
Key Observations- Tamil Nadu 2022

➢ Wind installation will be high as compared to solar by 2022.

➢ Ramp Up/Down or Net-Load variability is maximum ~ 23% instances/year with high Net-Load range during high RE-penetration.

➢ Low Net-Load range and highest Net-Load range are mainly during high RE and low RE time horizon respectively.

➢ The maximum Ramp-Up (maximum Net-Load variation) and Ramp-Down requirement (minimum Net-Load variation) per hour is ~2.6 GW/hour and ~2.5 GW/hour respectively with High Net-Load range.

➢ Based on the vRE generation dataset, a 2.5σ would cover majority of the vRE (Wind +Solar) variation for the state.

➢ At 2.5σ the maximum reserve requirement for the projected vRE generation is ~1800 MW.

➢ The reserve requirement is highest during peak hours in June-August period which coincides with high variations in wind and solar generation.
References


Back up
vRE output variation over a 15-minute period for Tamil Nadu -2022